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Design and Analysis of Crankshaft Used in Aerospace Applications and Comparision Using Different Materials.

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Abstract:The overall objective of this project was to evaluate and compare the fatigue performance of two competing manufacturing technologies for aerospace crankshafts, namely forged steel and ductile cast iron. In this project a dynamic simulation was conducted on two crankshafts, forged steel and ductile cast iron, from similar four cylinder four stroke engines. Finite element analysis was performed to obtain the variation of stress magnitude at critical locations. The pressure-volume diagram was used to calculate the load boundary condition in dynamic simulation model, and other simulation inputs were taken from the engine specification chart. The dynamic analysis was done analytically and was verified by simulations in ANSYS. Results achieved from aforementioned analysis were used in optimization of the forged steel crankshaft. Geometry, material, and manufacturing processes were optimized considering different constraints, manufacturing feasibility, and cost. The optimization Process included geometry changes compatible with the current engine, fillet rolling, and the use of micro alloyed steel, resulting in increased fatigue strength and reduced cost of the crankshaft, without changing connecting rod and or engine block.

Key words: Fatigue, Materials, Crankshaft, Ansys, Manufacturing

1)INTRODUCTION

1.1 MOTIVATION

Crankshaft is one of the most important moving parts in internal combustion engine. Crankshaft is a large component with a complex geometry in the engine, which converts the reciprocating displacement of the piston into a rotary motion. The reason for choosing this project is to design a typical crankshaft made of forged steel so that it can resist deformations in high speed engines.

1.2 PROBLEM DEFINITION

1. Crankshafts are typically manufactured by casting and forging processes.
2. Manufacturing by forging has the advantage of obtaining a homogeneous part that exhibits less number of micro structural voids and defects compared to casting.
3. In addition, directional properties resulting from the forging process help the part acquire higher toughness and strength in the grain-flow direction.
4. While designing the forging process for crankshaft, the grain-flow direction can be aligned with the direction of maximum stress that is applied to the component.

1.3 OBJECTIVE OF PROJECT

The objective of this project was to compare the durability of crankshafts from two competing manufacturing processes, as well as to perform static load and stress analysis. The crankshafts used in the study were forged steel and ductile cast iron from a four cylinder diesel engine. Strain controlled monotonic and fatigue tests as well as impact tests were performed on specimens machined from the crankshafts. Load-controlled component bending fatigue tests were also carried out on the crankshafts. Material tests showed that the forged steel had 21% higher tensile strength. Static load analysis was performed to determine the in service loading of the crankshafts and FEA was conducted to find stresses at critical locations.

2)LITERATURE REVIEW

2.1)I.C ENGINE

The internal combustion engine is an engine in which the combustion of a fuel (normally a fossil fuel) occurs with an oxidizer (usually air) in a combustion chamber. In an internal combustion engine the expansion of the high-temperature and -pressure gases produced by combustion applies direct force to some component of the engine, such as pistons, turbine blades, or a nozzle.

2.2)ENGINE STRUCTURAL PARTS

BEDPLATEFoundation on which the engine is built.Must be rigid enough to support the rest of the engine and hold the crankshaft which sits on the bearing housing in alignment with transverse girders.

FRAMELoad-carrying part of an engine.It may include parts as the cylinder block,base, sump and end plates.In two-stroke engines, frames are sometimes known as A-frames.

CYLINDER BLOCK Cylinder blocks for most large engines are made of castings and plates that are welded horizontally and vertically for strength and rigidity (stiffener).

CYLINDER HEAD The space at the combustion chamber top is formed and sealed by a cylinder head.The cylinder head of a four-stroke engine houses intake and exhaust valves, the fuel injection valve, air starting vale, safety valve.

Need and Objective:

The stress analysis in the fields of civil, mechanical and aerospace engineering, nuclear engineering is invariably complex and for many of the problems it is extremely difficult and tedious to obtain analytical solutions. With the advent of computers, one of the most powerful techniques that have been developed in the

engineering analysis is the finite element method and the method being used for the analysis of structures/solids of complex shapes and complicated boundary conditions.

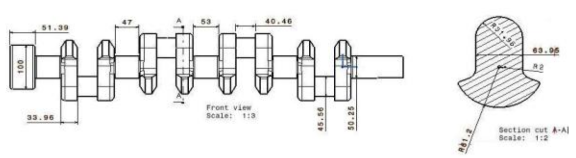
3)DESIGN

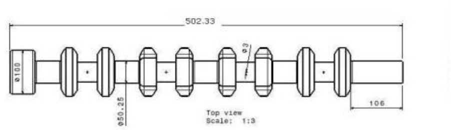
CATIA-V5 is unmatched in this field, in all processes, in all countries, in all kind of companies along the supply chains. Catia-v5 is also the perfect solution for the manufacturing enterprise, with associative applications, robust responsiveness and web connectivity that make it the ideal flexible engineering solution to accelerate innovations. Electrical and electronics goods, automotive, aerospace, shipbuilding and plant design. It is user friendly solid and surface modeling can be done easily.

<u>3.1)CRANKSHAFT DESIGN</u>

DATA FOR DESIGN CALCULATIONS:

Bore and Stroke :81×87.3 mm
Displacement : 1,799 cc
Rod Length : 142 mm
Rod/Stroke : 1.62
Compression : 10.5:1
Power : (128 hp/98kw) at 6000 rpm
Torque: 110 Nm @ 6200 rpm
Head Code : P28
Fly wheel: 7lb/31.13N
Compression pressure :15.5 bar(With S.C)
Combustion pressure :35.6 bar
Lp/Dp :3.1
Lc/Dc :0.8
Chain pull :4.5kN<30(H)
Pbp:14.83MPa
Pbc : 9.95 Mpa





3.2) DESIGN CALCULATIONS OF CRANKSHAFT:

Diameter of bore D	=	81 mm
Length L	=	87.3 mm
Power	=	128 hp/98 kw
Speed	=	6000 rpm
Compression	=	10.5:1
Head code	=	P 28
Fly wheel	=	7 lb/31.13 N
Compression pressure	=	15.5 bar
Combustion pressure	=	35.6 bar
Chain pull	=	4.5 KN
Diameter of crank pin	=	45.56 mm
Length of pin	=	40.46 mm

We have,

Gas force **$F_p = (\pi/4) \times D^2 \times P$**

$= ((\pi/4) \times 81^2 \times 35.6 \times 10^9)/1000000$

$= 18344.67$ N

b = 40.46+33.96+33.96+47

b = 155.38=156

Alsob=2D=162

$b_1=b/2$

$b_1=156/2$

=78 mm

$H_1= F_p \times (b_1/b)$

$=18344.67 \times (78/156)$

$H_1=9172.33$ N$=H_2$

$V_2 = W \times (c_1/c)$

$= 31.13 \times (78/156)$

$V_2 = 15.56$ N $=V_3$

$H_2^1= ((t_1+t_2) \times c_1)/c$

$= (4.5 \times 10^3 \times 78)/156$

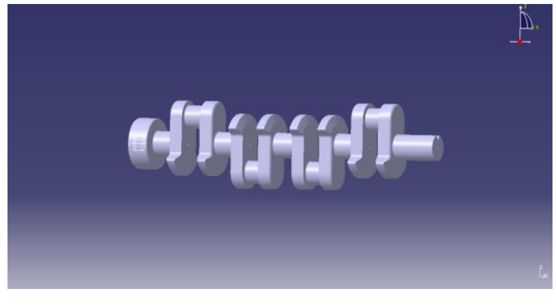
$= 2250$ N

3.3)DESIGN OF CRANK PIN:

Diameter of crank pin $d_c= 45.56$ mm
Length of crank pin $l_c= 40.46$ mm
Allowable bending stressσ_b =75 Mpa or (N/mm^2)
Bending moment for crank $M_c=H_1 \times b_2= 715441.74$ N-mm
Bending moment for Shaft
$= (\pi /32) \times d_c^3 \times \sigma_b$
$= 696352.50$ N-mm
At crank pin,
$715441.74 = (\pi/32) \times 45.56^3 \times \sigma_b$
$\sigma_b= 77.05$ N/mm^2 or Mpa

3.4)DESIGN OF SHAFT & FLY WHEEL:

Diameter of fly wheel = 100 mm
Width=51.39 mm
Bending moment due to weight of flywheel, $M_w = V_3 \times c_1 = 1213.68$ N-mm
Bending moment due to Belt tension, $M_t = H_2^1 \times c_1=175500$ N-mm
Therefore $M_s=175504.19$ N-mm
Also $M_s = (\pi/32) \times d_s^3 \times \sigma_b$
$M_s =(\pi/32) \times 100^3 \times \sigma_b$
$\sigma_b = 1.78$ N/mm^2 or Mpa



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4.ANALYSIS

ANSYS Mechanical and ANSYS Multiphysics software are non exportable analysis tools incorporating pre-processing (geometry creation, meshing), solver and post-processing modules in a graphical user interface. These are general-purpose finite element modeling packages for numerically solving mechanical problems, including static/dynamic structural analysis (both linear and non-linear), heat transfer and fluid problems, as well as acoustic and electro-magnetic problems.

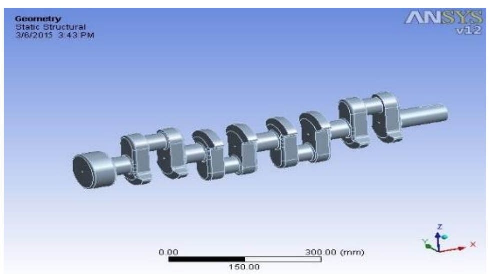
4.1)ANSYS WORKBENCH

ANSYS Workbench is a new-generation solution from ANSYS that provides powerful methods for interacting with the ANSYS solver functionality. This environment provides a unique integration with CAD systems, and your design process, enabling the best CAE results.

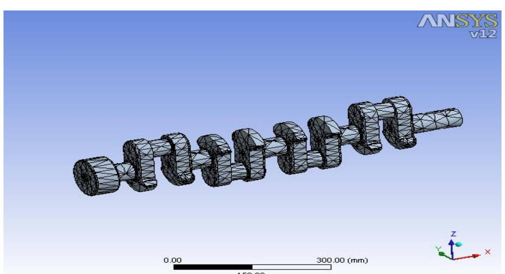
4.2)ANALYSIS OF THE CRANKSHAFT

MATERIAL-1: CAST IRON

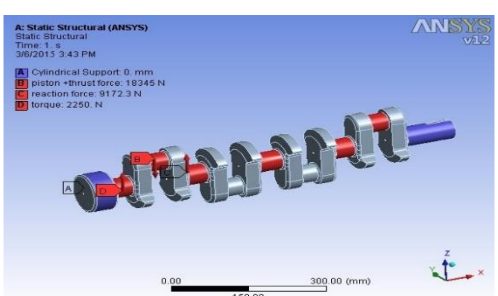
GEOMETRY



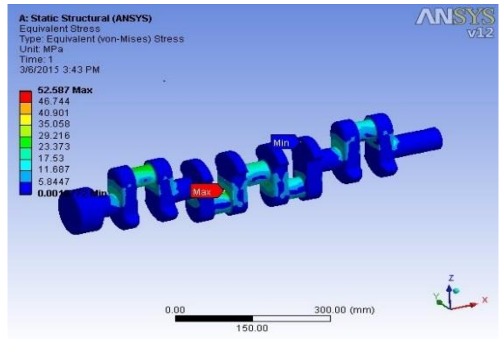
MESH



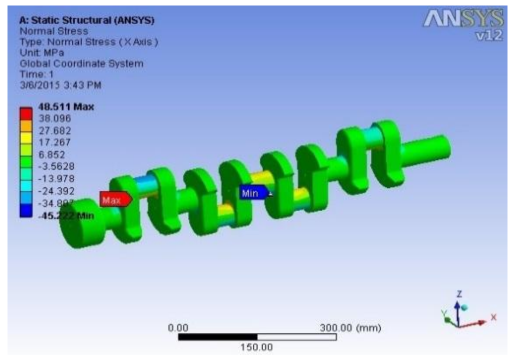
STATIC STRUCTURAL



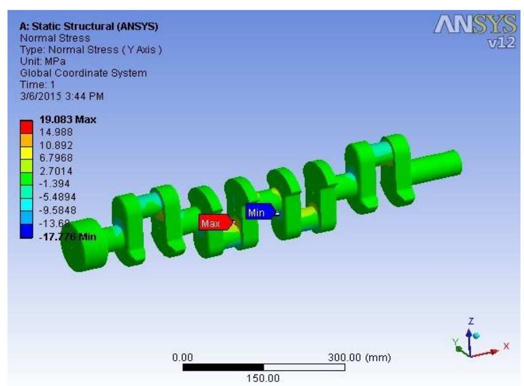
EQUIVALENT STRESS



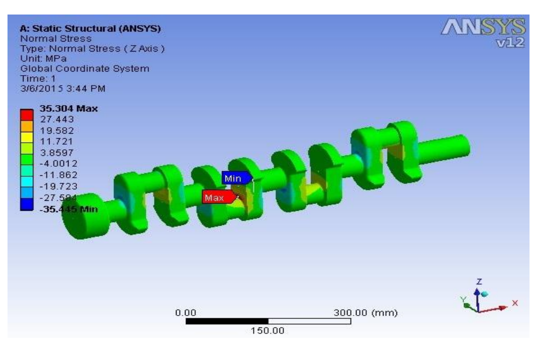
NORMAL STRESS: ALONG X-AXIS



NORMAL STRESS: ALONG Y-AXIS



NORMAL STRESS: ALONG Z-AXIS



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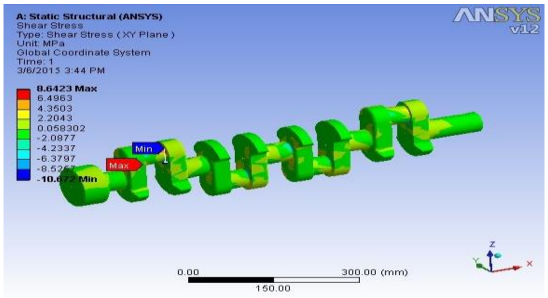
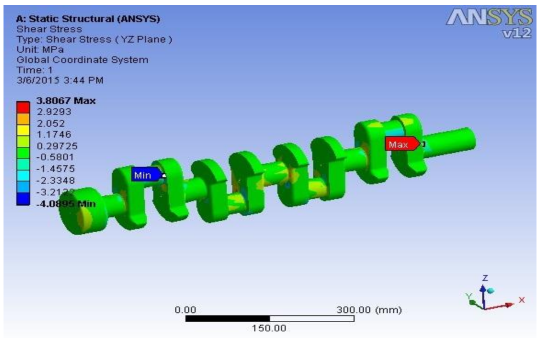
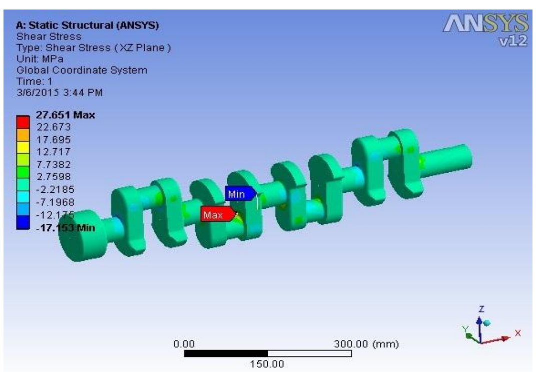
SHEAR STRESS: IN THE XY-PLANE



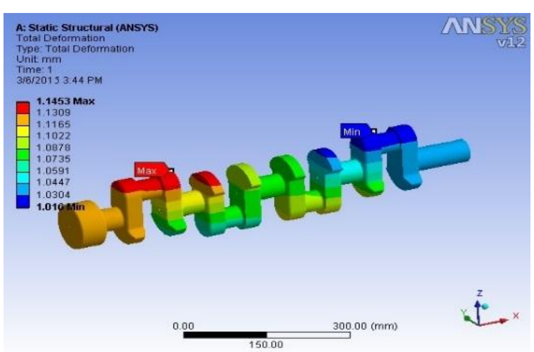
SHEAR STRESS: IN THE YZ-PLANE



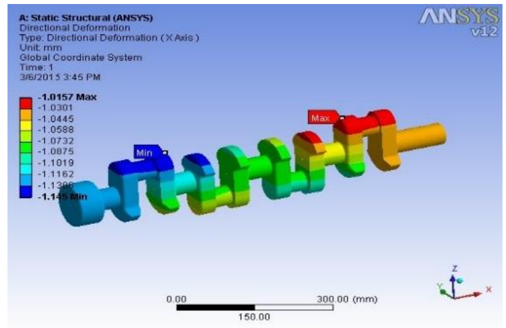
SHEAR STRESS: IN THE XZ-PLANE



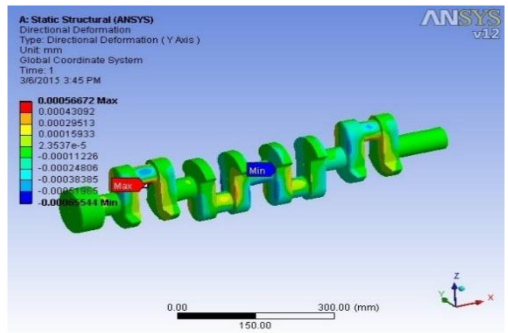
TOTAL DEFORMATION



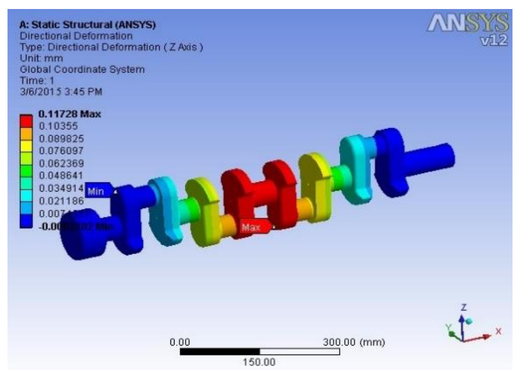
DIRECTIONAL DEFORMATION: ALONG X-AXIS



DIRECTIONAL DEFORMATION: ALONG Y-AXIS

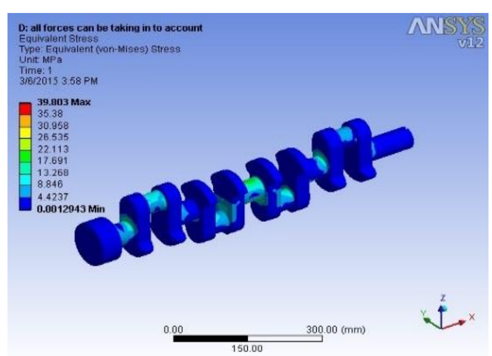


DIRECTIONAL DEFORMATION: ALONG Z-AXIS



MATERIAL-2: FORGED STEEL

EQUIVALENT STRESS



TOTAL DEFORMATION

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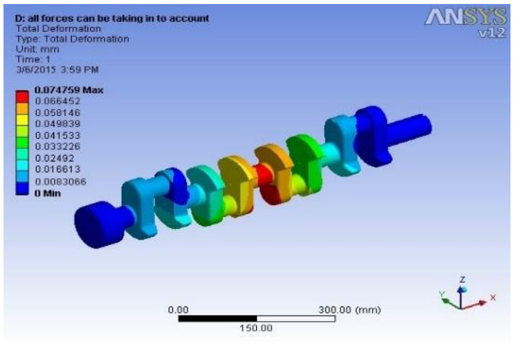
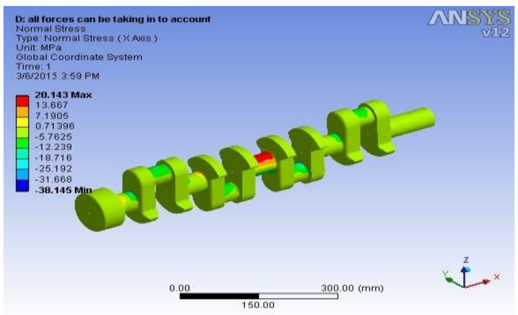
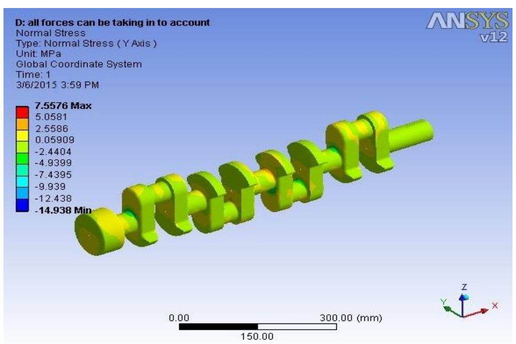


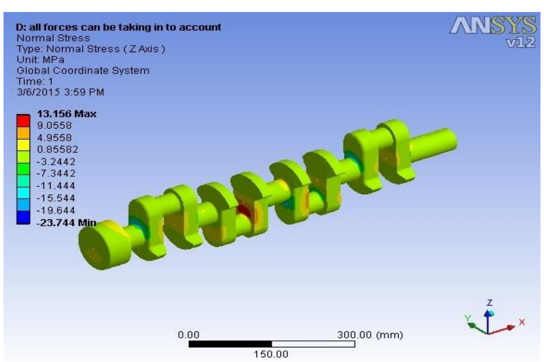
NORMAL STRESS: ALONG X-AXIS



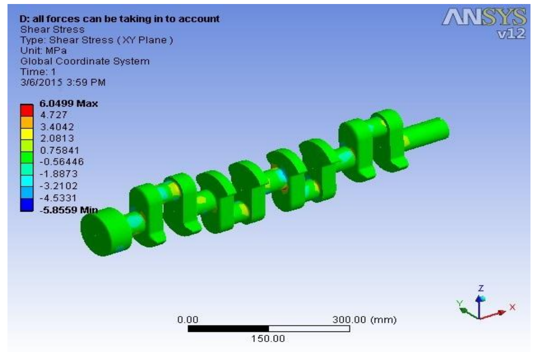
NORMAL STRESS: ALONG Y-AXIS



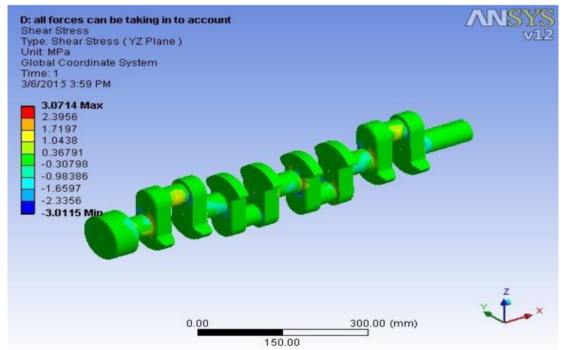
NORMAL STRESS: ALONG Z-AXIS



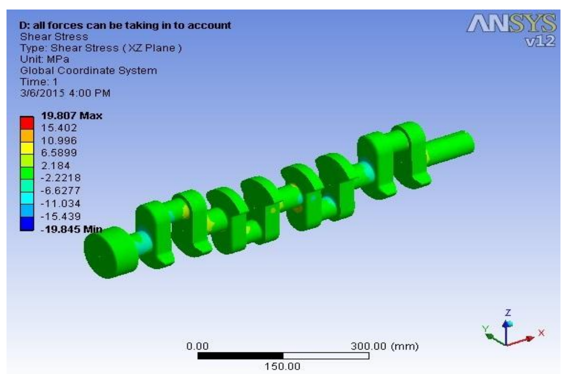
SHEAR STRESS: IN THE XY-PLANE



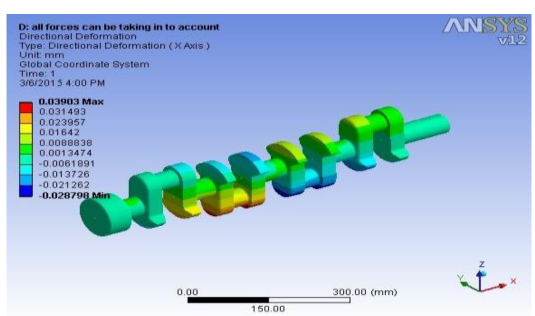
SHEAR STRESS: IN THE YZ-PLANE



SHEAR STRESS: IN THE XZ-PLANE



DIRECTIONAL DEFORMATION: ALONG X-AXIS



DIRECTIONAL DEFORMATION: ALONG Y-AXIS

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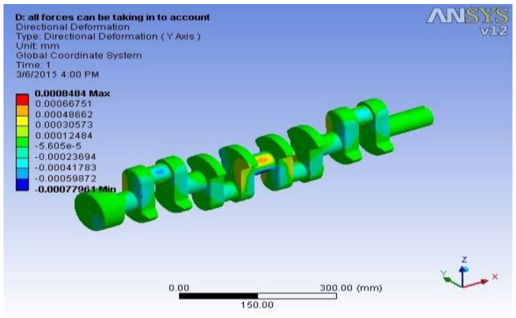
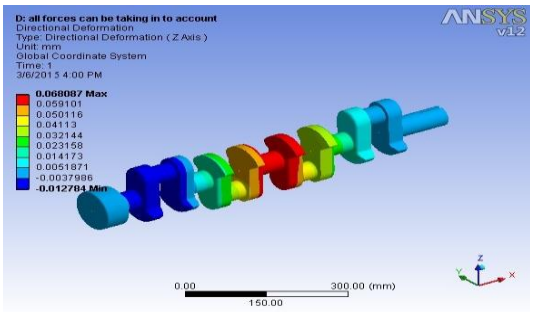


DIRECTIONAL DEFORMATION: ALONG Z-AXIS

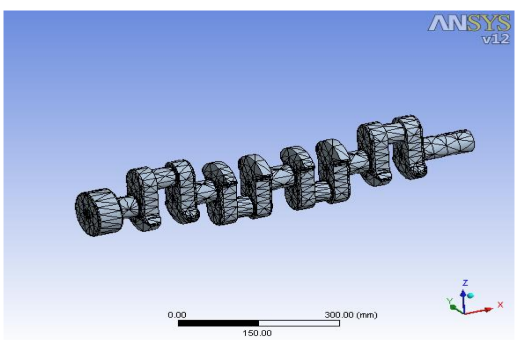


5) <u>IMPLEMENTATION AND RESULTS</u>

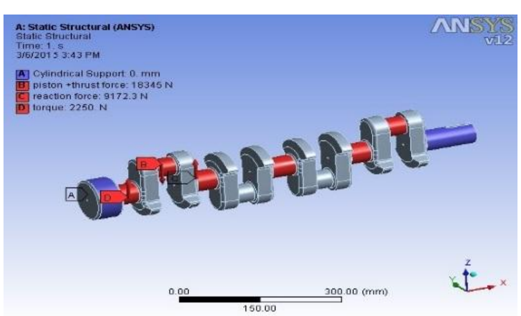
5.1 ANALYSIS OF CRANKSHAFT-CAST IRON

CAST IRON PROPERTIES

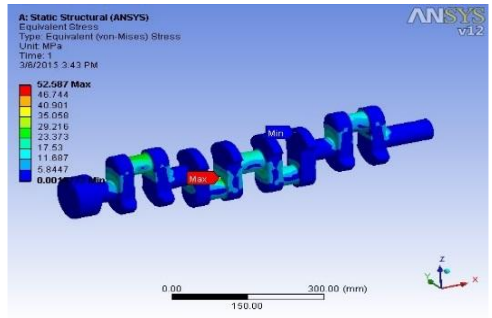
Young's Modulus	1.1e+005 MPa
Poisson's Ratio	0.28
Density	7.2e-006 kg/mm³



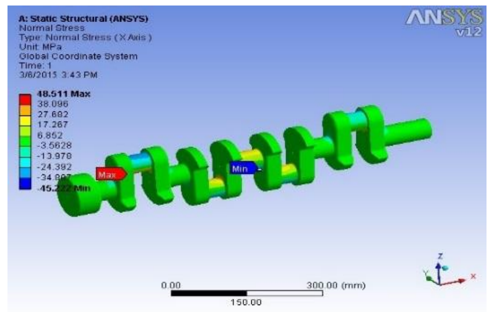
Crankshaft (cast iron) meshed



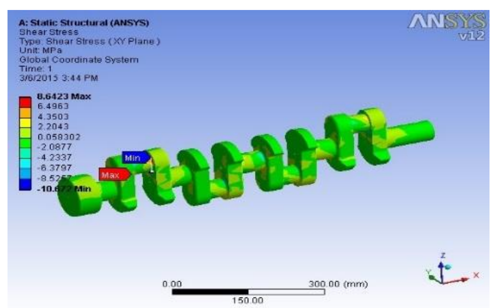
Crankshaft (cast iron) loading



Crankshaft (cast iron) equivalent (von-mises) stress



Crankshaft (cast iron) normal stress

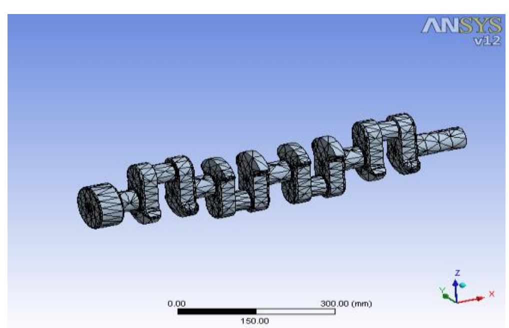


Crankshaft (cast iron) shear stress

5.2 ANALYSIS OF CRANKSHAFT-FORGED STEEL

FORGED STEEL PROPERTIES

Young's Modulus	2.e+005 MPa
Poisson's Ratio	0.3
Density	7.85e-006 kg/mm³



Crankshaft (forged steel) meshed

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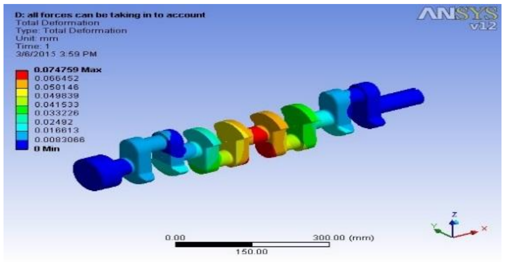
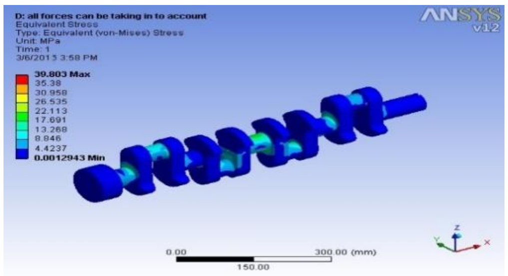
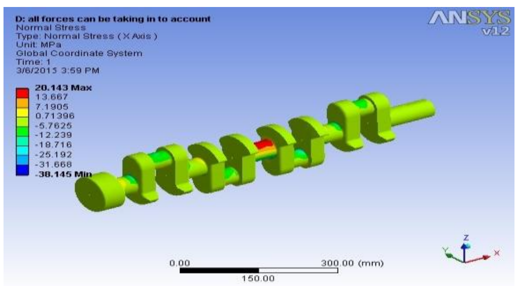


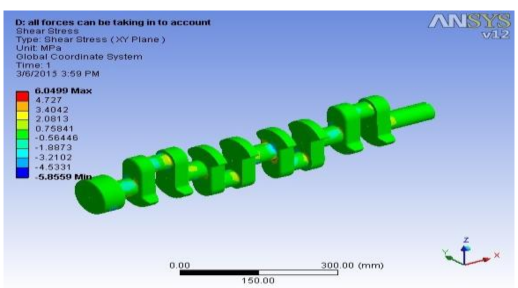
Crankshaft (forged steel) total deformation



Crankshaft (forged steel) equivalent (von-mises) stress



Crankshaft (forged steel) normal stress



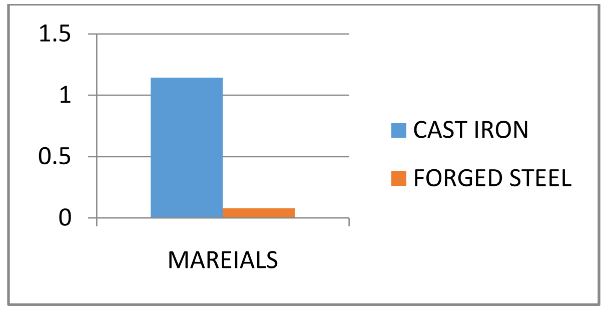
Crankshaft (forged steel) shear stress

COMPARISION OF PROPERTIES OF FORGED STEEL AND CAST IRON

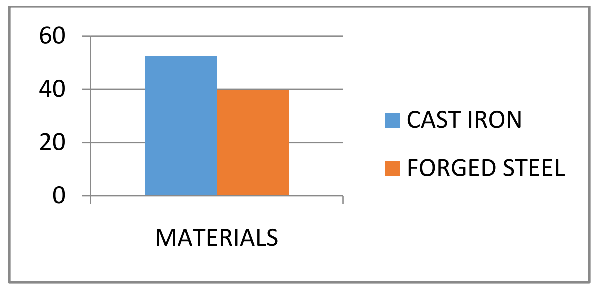
PROPERTIES	CAST IRON	FORGED STEEL
TOTAL DEFORMATION (mm)	1.1453	0.074759
EQUIVALENT (VON-MISES) STRESS	52.587	39.803
NORMAL STRESS	48.511	20.143
SHEAR STRESS	8.6423	6.0499

CHATS FROM THE ABOVE TABLE

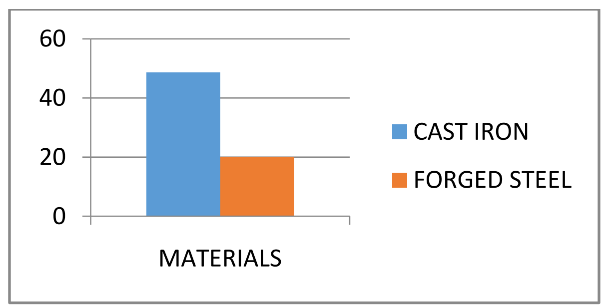
1. TOTAL DEFORMATION (mm)



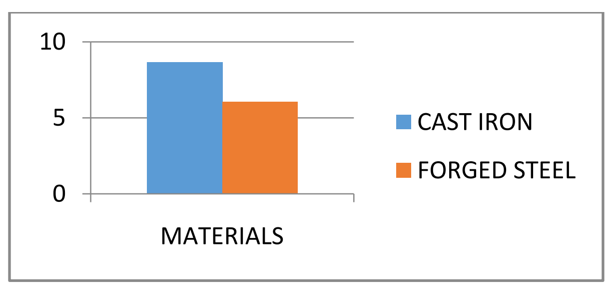
2. EQUIVALENT (VON-MISES) STRESS



3. NORMAL STRESS



4. SHEAR STRESS



CONCLUSION

Analysis results from testing the crank shaft under static load containing the stresses and deflection are listed in the Table. Since the forged iron crankshaft is able to withstand the static load, it is concluded that there is no objection from strength point of view also, in the process of replacing the cast iron crankshaft by forged crankshaft.

We also reduce forged crankshaft the cost by the mass production. The project carried out by us will make an impressing mark in the field of automobile industries. Doing this project we are study about the 3D modelling software (CATIA) and the Analyzing software (ANSYS) to develop our basic knowledge to know about the industrial design.

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